(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 413 311 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 90115589.5

(51) Int. Cl.5: H03G 3/20

(22) Date of filing: 14.08.90

(30) Priority: 16.08.89 JP 210084/89
23.03.90 JP 72055/90

(43) Date of publication of application:
20.02.91 Bulletin 91/08

(84) Designated Contracting States:
DE GB

(71) Applicant: HITACHI, LTD.
6, Kanda Surugadai 4-chome
Chiyoda-ku, Tokyo 100(JP)

Applicant: KOKUSAI ELECTRIC CO., LTD.
3-13, 2-Chome, Toranomon, Minato-ku
Tokyo-to(JP)

(72) Inventor: Nakagoshi, Arata, Hitachi
Keimei-Ryo
14-13, Honda-3-chome
Kokubunji-shi(JP)
Inventor: Tsukamoto, Nobuo
51-6, Ichibancho-1-chome
Tachikawa-shi(JP)
Inventor: Noguchi, Hiroshi
8-13-403, Shinmeidai-2-chome, Hamuramachi
Nishitama-gun, Tokyo(JP)
Inventor: Nakagawa, Junichi
29-16, Nakaarai-4-chome
Tokorozawa-shi(JP)
Inventor: Mitomo, Isamu
1429-329, Hatsuzawamachi
Hachioji-shi(JP)
Inventor: Hoshi, Atushi
2-1-KF 103, Shinmeidai-2-chome
Hamuramachi
Nishitama-gun Tokyo(JP)
Inventor: Horaguchi, Masato
9-25, Bunkamachi Wakabayashi-ku,
Sendai-shi(JP)

(74) Representative: Strehl, Schübel-Hopf, Groening
Maximilianstrasse 54 Postfach 22 14 55
D-8000 München 22(DE)

(54) A radio receiver and a radio receiver using a direct conversion.

(57) The present invention relates to a radio receiver for outputting a signal which has been demodulated from a radio frequency band signal received by an antenna, and in particular to a radio receiver which converts a radio frequency band signal into an intermediate frequency and then converts it into a digital signal for demodulating the same or a radio receiver using a direct conversion. The present invention is characterized in that an amplifier (2) for amplifying the radio frequency band signal received by the antenna comprises a variable gain amplifier and the radio receiver further includes a gain controller (3) for controlling the gain of the radio frequency variable gain amplifier.

EP 0 413 311 A2

A RADIO RECEIVER AND A RADIO RECEIVER USING A DIRECT CONVERSION

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a radio receiver which converts a radio frequency band signal into a low frequency band signal and then converts it into a digital signal for demodulating the same or a radio receiver using a direct conversion.

Description of the Related Art

An example of a first prior art receiver is shown in Fig. 28. The first prior art receiver converts the frequency of the received frequency-modulated signal into an intermediate frequency (IF) and thereafter converts the IF signal into a digital signal by means of an A/D converter for conducting frequency band limitation, amplitude limitation and demodulation of the frequency-modulated signal by digital signal processing techniques. In Fig. 28, a received signal having a radio frequency falling in an RF band including a plurality of channels is inputted into an RF amplifier 16 via an antenna. The received signal which is amplified by an RF amplifier 16 is then inputted into a mixer 5. In a usual receiver, a band pass filter is interposed between the RF amplifier 16 and the mixer 5 for preliminarily selecting frequency modulated signals of all channels which are desired to be received. In the mixer 5, the frequency of the received signal is converted into an IF band depending on the frequency of a local oscillation signal from a local oscillator 6 and the frequency of the received signal. The received signal, the frequency of which has been converted into an IF band, is amplified in an IF band variable gain amplifier 7 and is then converted into a digital signal by an A/D converter 10. Since an over-input level of the inputted signal causes the A/D converter 10 to be saturated to generate distortion in the received signal, the gain of the IF band variable gain amplifier 7 is changed via a gain controller 8 depending upon the output level of the IF band variable gain amplifier 7 which is detected by a level detector 9. In such a manner, the input level of the A/D converter 10 is controlled so that it will not exceed a preset value. Although signal level may be expressed by effective value or wave height value and what is expressed by the output value is different depending upon the configuration of the circuit of the level detector, the level is expressed by effective value herein for convenience of description. Following digital signal level will be similarly expressed.

The received signal which has been converted into a digital signal by the A/D converter 10 is then inputted into a digital filter 11 at which only a signal which is desired to be modulated (hereinafter referred to as desired signal) is selected from a plurality of channels. The desired signal is subject to amplitude limitation suitable for the characteristics of the demodulator before the desired signal which is an output of the digital filter 11 is applied to the modulator 14. The output of the digital filter 11 is inputted to a digital level detector 13 for limiting the amplitude of the desired signal by a limiter 12 by using the result of the level detection of the digital level detector 13. The desired signal, the amplitude of which has been limited, is inputted to the modulator 14 for demodulation.

A second prior art radio receiver is described in IEEE, Proc. Vol. 129, Pt, F, No. 1 (1982. 2) pp. 2 through 6. A basic structure of a direct conversion receiver is shown in Fig. 30. A received signal including a plurality of channels is inputted from an antenna via an input terminal 1 to an RF amplifier 20. The received signal which is amplified by the RF amplifier 20 is divided into two signals and the divided signals are inputted to two mixers 5I and 5Q, respectively. A local oscillator 6 generates a local oscillation signal having an oscillation frequency substantially equal to a carrier frequency of a signal of a channel which is desired to be received (hereinafter referred to as desired signal). The local oscillation signal is splitted into two signals and phase-shifted by a splitter and phase shifter 104 so that the split two oscillation signals are 90° out of phase. The mixers 5I and 5Q conduct frequency conversion of split two received signals outputted from the RF amplifier 20 by mixing them with two output signals from the splitter and phase shifter 104. Two received signals which have been subject to frequency conversion are amplified by intermediate frequency amplifiers 21I and 21Q and then are subject to frequency band limitation by low-pass filters 22I and 22Q for selecting desired signals. Two desired signals which have been selected by the low-pass filters 22I and 22Q are subjected to amplitude limitation depending upon the characteristics of a modulator by a limiter 23. Two desired signals having a limited amplitude are inputted to the demodulator

24 for demodulating the received signals and the demodulated signals are outputted from an output terminal 15 via a low-pass filter 25. In principle, the direct conversion receiver has features that frequency band limitation in a radio frequency band is not needed and the receiver may be readily manufactured from ICs since the frequency of the received signal after frequency conversion is low. For example, an IC for the direct conversion receiver is commercially available from Plessey Semiconductor Co., Ltd. as a Model "SL6637".

SUMMARY OF THE INVENTION

Although above-mentioned prior art of the first and second receivers takes a measure for an over-input to the analog-to-digital converter 10, it takes no measure for an over-input to the RF amplifier 16 and the mixer 5. Accordingly, it invites various problems which will be hereafter described.

Input-to-output characteristics in automatic gain control at an intermediate frequency in the prior art as mentioned above will be described. Fig. 29 concerns with a system including the intermediate frequency band variable gain amplifier 7 which is subjected to a usual automatic gain control for illustrating the relation between the radio frequency input signal level at the input terminal 1 and the radio frequency input signal level at the intermediated frequency band variable gain amplifier 7. Abscissa denotes a radio frequency input level and ordinate denotes an intermediate frequency output level. Specifically, the levels correspond to the radio frequency input level at the radio frequency amplifier 16 and the intermediate frequency output level of the intermediate frequency variable gain amplifier 7 in Fig. 28, respectively. Description of unit in Fig. 29 is omitted since Fig. 29 is a schematic view.

When the radio frequency input level is low, the gain controller 8 does not carry out gain control to the intermediate frequency band variable gain amplifier 7, resulting in that linearity of the input-to-output characteristics is maintained until the radio frequency input level reaches A point as shown in Fig. 29.

When the radio frequency input level exceeds a point A, that is, the intermediate frequency reaches a point B, the level detector 9 and the gain controller 8 changes the gain of the intermediate frequency gain variable amplifier 7 so that the intermediate frequency output level will not exceed the point B. In this case, the basic operation of the automatic gain control comprises providing the gain controller 8 with information for lowering the gain of the IF band variable gain amplifier 7 when the IF output level which is detected by the level detector 9 exceeds a value corresponding to point B of the IF output level. The gain controller 8 receives information from the level detector 9 for operating the IF band variable gain amplifier 7 to lower the gain of the IF band variable gain amplifier 7. When the IF output level is lower than the point B by the above-mentioned gain control operation, the level detector 9 provides the gain controller 8 with information for increasing the gain of the IF band variable gain amplifier 7. Thus, the IF output level is fixed at the point B by the above-mentioned gain control loop. The IF output level may be fixed at the point B within the variable gain range of the IF band variable gain amplifier if the RF input level is above the point A. There will be transient areas of gain control before and after the point A in a practical circuit.

Since the above-mentioned automatic gain control is performed before selection of a desired signal, output level control is performed for mixed signals on a plurality of channels.

Accordingly, if the input level of a desired signal is low and the input level of received signals on other channels (hereafter referred to as undesired signals) is high, and the points A and B shown in Fig. 29 are preset at a low level, gain control of the IF band variable gain amplifier 7 is performed depending on the level of undesired signals, resulting in that the output level of a desired signal is suppressed as well as those of undesired signals and the reception sensitivity will be lowered. Therefore, the gain control range should be preset by considering decrease in sensitivity of the receiver.

Influence of inter-modulation will now be described. Amplification and frequency conversion of mixed received signals on a plurality of channels newly generates undesired signals due to inter-modulation. For simplicity of explanation, influence of inter-modulation will be described with reference to mixed signals including signals on three channels. It is assumed that a desired signal D_1 has a carrier frequency of f_1, undesired signals y_1 and v_2 have carrier frequencies f_2 and f_3, respectively, and the carrier frequencies are equally spaced and have a relation as follows:

$f1 < f2 < f3$

$f3 - f2 = f2 - f1 = df$

Only tertiary components are taken out from intermodulated signals generated with two undesired signals and may be represented as follows:

$fi1 = 2f2 - f3 = f2 - df = f1$

$fi2 = 2f3 - f2 = f2 + df$

FIG. 28
PRIOR ART

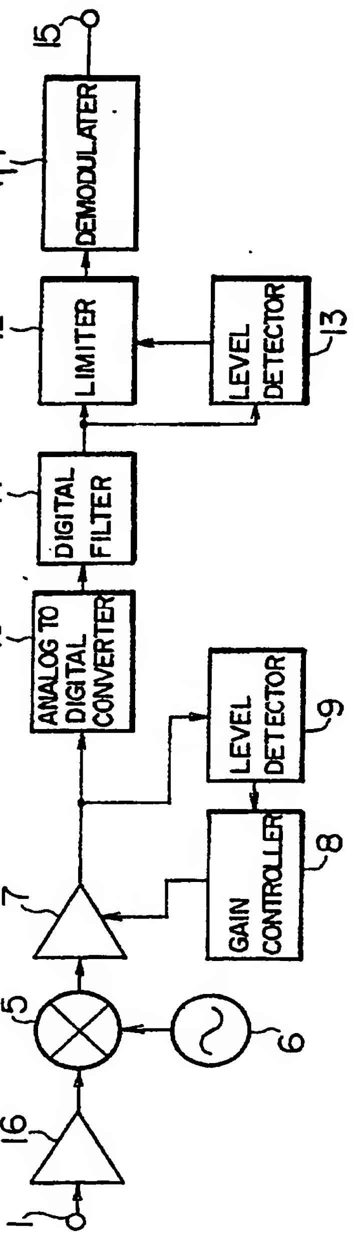

FIG. 29 PRIOR ART